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Effects of Uncertainty Markers on Metacognitive Group Awareness and Regulation

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Abstract: Social platforms provide a vast amount of resources for sharing, discussing, and searching for information. Thereby, learners need to monitor their understanding to metacognitively regulate their learning. Awareness of peers' metacognitions can affect individual regulation processes and such information may be communicated through language characteristics. Thus, in our experimental study (N = 214), we examined the effects of uncertainty markers in a social media forum setting on perceptions of uncertainty within the group as well as changes in learners' content-related assumptions, certainty, and learning intention. Results confirmed the influence of uncertainty markers on perceived uncertainty within the group, which in turn affected the learners' changes in assumptions and learning intention via changes in certainty. Further exploratory analyses showed that the effect of perceived group uncertainty on own certainty was stronger for men than for women. This study confirms the intricate nature of individual and social metacognitive processes in online learning.

Metacognitive awareness and learning regulation

Digital learning environments enable location- and time-independent accessibility as well as interactive, individualized, and adaptive learning. Online environments also provide a digital space for collaborative learning, in which learners can work collectively on authentic learning problems and their solutions (e.g., Mäkitalo et al., 2005). Additionally, social media platforms provide a vast amount of resources for sharing, discussing, and searching for information. This extends to wikis and discussion forums (e.g., Heimbuch et al., 2018) or social networking sites (e.g., Tsovaltzi et al., 2015), where users potentially interact with a large number of often unknown users. In these contexts, individual and collaborative learning activities alternate with some learners actively contributing and others mostly consuming the externalized learning processes of others. Thus, like in other individual learning contexts, learners need to make various relevant learning decisions and metacognitively regulate their learning. However, they are also influenced by their social context.

Metacognition is essential for regulating individual and collaborative learning processes (e.g., Salonen et al., 2005) and is understood as "knowledge and cognition about cognitive phenomena" (Flavell, 1979, p. 906). Metacognitive planning, monitoring, and regulation enable learners to productively and reflectively use adequate learning strategies to achieve learning goals. Thereby, metacognitive monitoring of own knowledge and learning plays a central role in metacognitive models of self-regulated learning (e.g., Winne & Hadwin, 1998), as it forms the basis for controlling learning activities (Nelson & Narens, 1990; Thiede et al., 2003) and thus study success (e.g., Thiede, 1999). A learner's assessment of how well they have understood a topic influences whether they consider further learning necessary and this thus may affect their intention to learn (Renner & Renner, 2001; Von der Linden & Roebers, 2006). Metacognitive monitoring of own knowledge may result in experiences of certainty or uncertainty with regard to specific assumptions. Uncertainty can have a motivational effect (Anselme, 2010) and leads to an increase in engagement in learning (Howard-Jones & Demetriou, 2009; Ozcelik et al., 2013). Uncertainty can further increase and guide information-seeking behavior and when learners close perceived gaps within their knowledge, uncertainty is reduced (e.g., Schnaubert & Bodemer, 2016, 2017). Additionally, uncertainty is related to a lack of supporting evidence for specific assumptions (e.g., Gigerenzer et al., 1991; McGarty et al., 1993) and has thus been linked to an increase in changes in assumptions (Schnaubert et al., 2021). From a metacognitive perspective, it thus seems logical that learners may use uncertainty as an indicator for gaps in knowledge and may thus increase their intention to seek further information and learn when uncertain, but that learners uncertain are also more prone to change their assumptions regarding the learning content.

While even in individual digital learning environments, social processes may play an important role for learning (see Schneider et al., 2022), social platforms additionally provide a context for learners to communicate and interact. Awareness information about the social context may severely affect individual learning and also metacognitive regulation (Schnaubert & Bodemer, 2016; Schnaubert et al., 2021). Thus, in addition to individual metacognitions formed through metacognitive monitoring, there are also social metacognitions, which are based on monitoring of knowledge, emotions, and actions of other learning group members (Chiu, 2008). Social metacognitions convey what beliefs the other learners have, what mental and emotional state they are in, and how they envision effective collaboration (Jost et al., 1998). Being aware of others' metacognitions can facilitate

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collaboration processes during collaborative learning (e.g., Dehler et al., 2011; Schnaubert & Bodemer, 2019). Active social metacognitive monitoring may additionally help learners to identify their own cognitive and metacognitive mistakes. By actively engaging with others' metacognitive views and strategies, learners get the opportunity to adjust their own metacognitions (Schnaubert et al., 2021). Because of this, own metacognitive experiences can also be strongly influenced by social processes (Carr & Jessup, 1997). For example, Karabenick (1996) found that the more questions peer-students ask about the learning material, the greater becomes the learners' reported confusion about the content of that material because of perceived uncertainty in a classroom. Thus, monitoring other learners' metacognitions may provide information relevant to judge other learners, their assumptions, or the task at hand and may thus lead to changes in own metacognitive judgments (e.g., Schnaubert et al., 2021). These adjusted judgments may then be used as a basis for metacognitive regulation as frequently observed in individual learning (e.g., Thiede et al., 2003).

To test how awareness of others' metacognitions influences individual metacognitive monitoring and self-regulation, Schnaubert and colleagues presented metacognitive group awareness information to learners in the form of uncertainty ratings of their peers and found learners to converge towards these peers and regulate their learning processes accordingly (Schnaubert & Bodemer, 2016; Schnaubert et al., 2021). While it seems reasonable that learners take their social context into account when regulating learning in digital and social learning environments, these studies presented peer awareness information explicitly and it remains unclear, if the results found may be transferred to learning scenarios void of group awareness tools. In real-life learning contexts, learners rarely judge their certainty and present the information to their peers, but metacognitive processes may be communicated through words, actions, or facial expressions. Thus, it is assumed that learners can build group awareness (i.e., the salient perception of group characteristics; Bodemer & Dehler, 2011) by monitoring social interaction and extracting partner- or group-related information (e.g., Engelmann et al., 2009).

In digital learning environments, uncertainty in own assumptions can be conveyed in textual messages through the use of the co-called uncertainty markers (e.g., Jordan & McDaniel, 2014). These include, for example, interjections used as fillers (e.g., "well…", "so…"), hedges (e.g., "somehow", "perhaps"), but also self-referential phrases (e.g., "as far as I know") and sentences that report mental states reflecting metacognitive awareness of uncertainty like "I am not quite sure" (e.g., Durik et al., 2008; Jordan & McDaniel, 2014). The use of uncertainty markers may thus convey a lack of internal uncertainty associated with lack of knowledge (e.g., Juanchich et al., 2017) and leads to a weakening of the persuasiveness of the presented assumption (e.g., Blankenship & Holtgraves, 2005; Hosman et al., 2002), as uncertainty affects how speakers as sources of information are perceived (e.g., Price & Stone, 2004; Tenney et al., 2011). According to Green (1984), the interlocutor's uncertainty can be identified by three categories of particular expressions: (1) certain frequency adverbs (e.g., "often" or "rarely"), (2) adverbs that convey the psychological uncertainty of the person speaking (e.g., "expected" or "desperate"), and (3) modal verbs and linguistic devices that represent ambiguous uncertainty (e.g., "could" or "maybe"). Further speech or text characteristics (e.g., ellipses ("...") at the end of a sentence) may indicate missing information and be associated with incomplete knowledge or uncertainty. Uncertainty markers that occur in both spoken and written language include also tag questions as well as hypotheticals (if-sentences; e.g., Bernstein, 1962). It can thus be concluded, that various language characteristics may be associated with uncertainty as metacognitive characteristic of the speaker and may influence metacognitive group awareness (i.e., the salient perception of metacognitions of other learners or the group; Schnaubert & Bodemer, 2019).

Based on the above described literature, we assume uncertainty markers in social media posts to affect metacognitive group awareness and thus increase the perceived uncertainty that learners attribute to the social group (H1). It was further established that uncertainty within a group may affect own metacognitive evaluations of certainty (see also Schnaubert et al., 2021) and we thus assume perceived uncertainty within social media posts to reduce the level of certainty of social media consumers (H2). As uncertain learners are more likely to change their assumptions about the learning content (e.g., Schnaubert et al., 2021), we assume perceived uncertainty within a social group to positively affect changes in assumptions via an increase in individual uncertainty (H3). Following the argumentation above, perceived uncertainty within social media posts is further assumed to positively affect the intention to learn by promoting individual uncertainty via an increase in perceived group uncertainty (H4).

While the assumed processes are based on theory and empirical findings concerning general mechanisms of metacognition, differential effects are largely unknown. One characteristic frequently associated with differences in certainty and social perception is gender. While there are several empirical findings that reveal gender-specific differences in metacognitive processes in learning and self-regulation (e.g., Bidjerano, 2005; Zimmerman & Martinez-Pons, 1990), how they are influenced by social aspects of metacognition is unclear. Thus, as a first step, we will additionally exploratively analyze if gender affects how perceptions of uncertainty within a social group affect own metacognitive assumptions (E1).

Methods

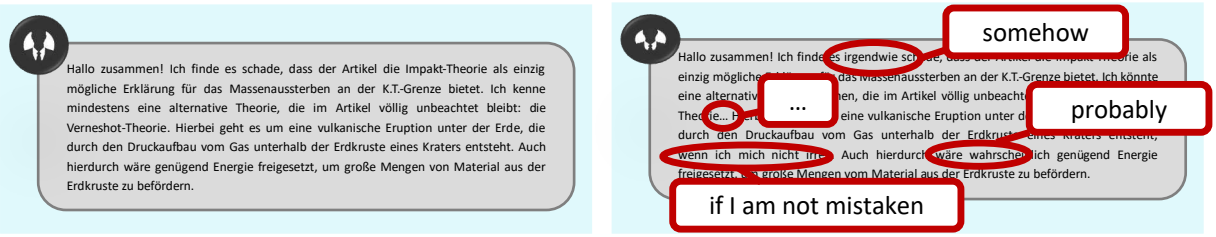
N = 220 participants initially completed the online study (ID: psychmeth_2020_MCSM_06), which was approved by the local ethics committee (vote: 2005PFSA4986). We excluded four participants with a reading speed above 600 words per minute as it can be assumed that they did not engage attentively and with full comprehension of the study content (e.g., Carver, 1990). We also excluded two participants who took a considerably long time to complete the study (> 1h) as this indicates interruptions or off-screen periods. The remaining sample thus consisted of *N* = 214 participants (*n* = 107 in each experimental group). The average completion time of these participants was 14 minutes and 37 seconds (*SD* = 7.35; range: 03:43–36:43 minutes). 133 of the remaining participants (62.1%) were women and 81 men (37.9%). Their age ranged from 18 to 68 years (*M* = 26.88, *SD* = 9.15), 104 had completed secondary school as their highest degree (high school or equivalent: 94 / 43.9%; lower secondary school: 10 / 4%) and 110 had an additional university degree (bachelor: 86 / 40.2%; master: 24 / 11.2%).

Design and procedure

At the beginning of the study, participants were randomly assigned to one of two experimental conditions. The conditions differed in the wording of the forum messages they received during the second reading phase, in which they read a discussion in a forum. One group received text messages with uncertainty markers during the study (UM+) and the other received text messages without markers (UM-) (cf. figure 1). Uncertainty markers were taken from the above described categories and we ensured that the text messages still read natural.

Figure 1

Examples for the uncertainty markers in text massages without UM (left) and with UM (right)



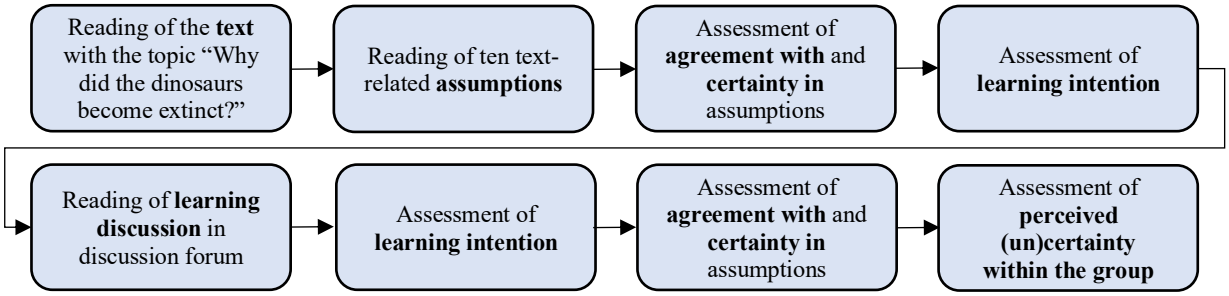
After giving informed consent and answering a number of questionnaires (e.g., self-efficacy, self-monitoring), all participants read a text with the topic "Why did the dinosaurs become extinct?". The text was based on materials from Heimbuch and Bodemer's (2017) adaptation of Buder and Bodemer's (2011) learning material on the extinction of dinosaurs, who used it to study group awareness in wiki-based learning. Subsequently, the participants read ten text-related assumptions (e.g., "The glass spherules around the Chicxulub crater are clear evidence that there was a meteorite impact 65 million years ago.") and expressed their agreement or disagreement with each assumption ("Do you agree with this assumption?"; *yes* vs. *no*). After each of the ten assumptions, the participants were asked about the certainty in their assessment ("How certain are you that your assumption is correct?") on six-point scale from 1 (*not certain at all*) to 6 (*completely certain*) (cf. Schnaubert & Bodemer, 2019). Afterwards, the participants' learning intention was recorded ("Would you like to look at further learning materials on this topic in the future?"). Participants were offered a six-point scale to answer, from 1 (*definitely not*) to 6 (*definitely*). Afterwards, the participants read the discussion in the online forum. The discussion threads each consisted of 14 posts with either 602 (UM-) or 719 (UM+) words. The content of the discussions between the experimental groups was identical, but the messages in the forum of UM+ contained uncertainty markers to convey uncertainty, while the messages in UM- did not (cf. figure 1). Subsequently, the participants were asked again whether they would look at further learning materials on this topic in the future to determine possible changes in their learning intention. Following, the participants had to express their (dis)agreement with the same ten text-related assumptions in the same order again and had to judge their certainty in their assessment. We further assessed the perceived (un)certainty within the learning group by having all participants rate the certainty of the contributors in the discussion forum on a scale from 1 (*not certain at all*) to 6 (*completely certain*) (this measure was later recoded; see below). The procedure is shown in figure 2.

Dependent variables

The dependent variables were calculated as follows: The number of *changes in learning assumptions* was determined by counting the number of assumptions (0 to 10) participants changed from "yes" to "no" or vice versa after reading the forum discussion. A higher value thus indicates more changes. *Changes in learning intention* was operationalized as the difference between learning intention before and after reading the discussion

(-5 to +5). A positive value indicates an increase in learning intention from pre to post while a negative value indicates a decrease. *Changes in own certainty* were calculated as the difference between the average certainty in own assumptions before and after reading the learning discussion (-5 to +5). Positive values indicate participants gaining certainty in their assumptions while negative values indicate losing certainty from pre to post. *Perceived uncertainty within the group* was determined by recoding the perceived certainty score (1 to 6) so that higher numbers indicate perceiving the group as more uncertain while lower numbers indicate perceiving it as certain.

Figure 2
Procedure



Results

Table 1 provides an overview over descriptive statistics of the dependent variables and their intercorrelations. We first tested if uncertainty markers in text messages caused learners to perceive their learning group as more uncertain (H1). A *t*-test for independent samples showed that there was a significant difference in the perceived certainty of the learning group between both experimental groups ($t(212) = 7.58$, $p < .001$, $d = 1.04$), with participants in UM- (without uncertainty markers) perceiving their learning group to be less uncertain and thus more certain ($M = 3.00$, $SD = 1.41$) than participants in UM+ ($M = 4.42$, $SD = 1.33$), supporting H1.

Using the SPSS software PROCESS macro (version 3.5) by Hayes (2017), we conducted simple mediation analyses (PROCESS model 4) to test the direct effect (H2) as well as the mediation hypotheses (H3 and H4). We found a significant total effect of *perceived uncertainty within the group* on *changes in learning assumptions* (ß = 0.22, $p < .001$, 95% CI [.09, .35]; cf. figure 3, left). We also found a significant negative effect of *perceived uncertainty within the group* on *changes in own certainty* (ß = -0.42, $p < .001$, 95% CI [-.55, -.30]), supporting hypothesis H2. Further, we founded a significant negative effect of *changes in own certainty* on *changes in learning assumptions* (ß = 0.32, $p < .001$, 95% CI [.46, .18]). As assumed in hypothesis H3, the analysis thereby revealed a significant indirect effect of *perceived uncertainty within the group* on *changes in learning assumptions* mediated by *changes in own certainty* (effect = 0.13, 95% CI [0.07, 0.22]). We founded no direct effect of *perceived uncertainty within the group* on *changes in learning assumptions* (ß = 0.08, $p = .235$, 95% CI [-.06, .22]) after controlling for the indirect effect. Taking together, the link between *perceived uncertainty within the group* and *changes in learning assumptions* is mediated by *changes in own certainty*.

In order to test the hypothesis H4, we calculated simple mediation analysis with *changes in learning intention* as dependent variable (cf. figure 3, right). We found a significant total effect of *perceived uncertainty within the group* on *changes in learning intention* (ß = 0.29, $p < .001$, 95% CI [.16, .42]). *Changes in own certainty* thereby significantly affected *changes in learning intention* (ß = -.43, $p <. 001$, 95% CI [-.56, -.30]) and there was a significant indirect effect of *perceived uncertainty within the group* on *changes in learning intention* mediated by *changes in own certainty* (effect = 0.18, 95% CI [0.09, 0.29]). *Perceived uncertainty within the group* had no direct effect on *changes in learning intention* after controlling for the indirect effect (ß = .11, $p = .114$, 95% CI [-.03, .24]). Thus, the effect of *perceived uncertainty within the group* on *changes in learning intention* is mediated by the participants' *changes in own certainty*, supporting H4.

Table 1
Means, standard deviations, and correlations with confidence intervals

Variable	*M*	*SD*	1	2	3
1. Perceived Uncertainty within the Group	3.71	1.54			
2. Changes in own Certainty	-0.03	0.66	-.423** [-.52, -.31]	(−)	
3. Changes in Learning Assumptions	2.14	1.79	.219** [.08, .36]	-.353** [-.47, -.21]	(−)
4. Changes in Learning Intention	-0.11	1.11	.288** [.13, .43]	-.476** [-.62, -.32]	.325** [.18, .46]

Note. $N = 214$; values in square brackets indicate the 95% confidence interval for each coefficient. Two-tailed significance: ** $p < .01$

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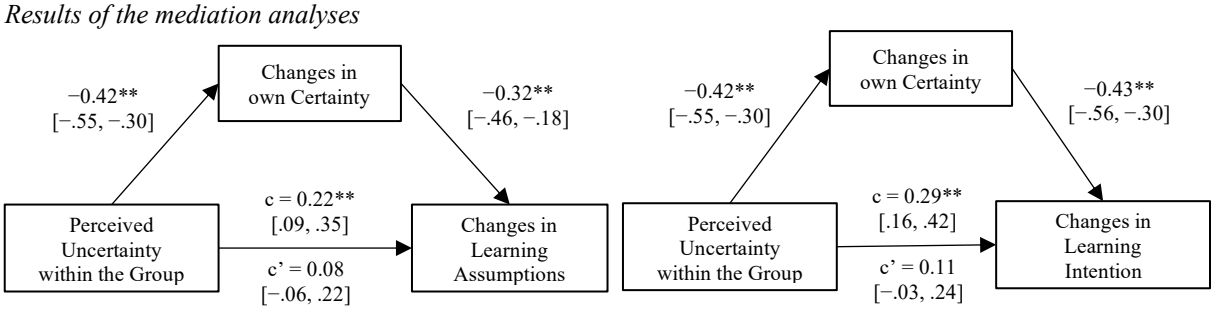
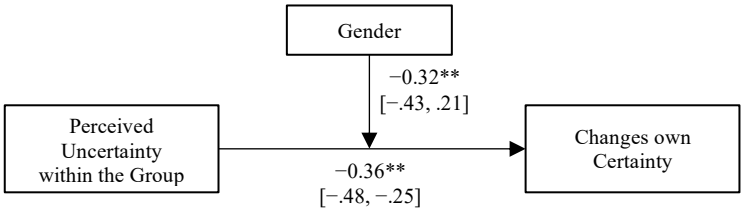
Figure 3
Results of the mediation analyses



Note. c = total effect; c' = direct effect; values in square brackets indicate the 95% confidence interval. Two-tailed significance: ** $p < .01$

Exploratively, the moderating effect of gender on the relationship between the *perceived uncertainty within the group* and *changes in own certainty* was investigated (E1). The moderation analysis showed a significant moderation effect: ß = -0.32, $p < .001$, 95% CI [-.43, -.21] (cf. figure 4). This means that *perceived uncertainty within the group* leads to significantly greater reductions in the men's certainty compared to women's.

Figure 4
Results of the moderation analysis of gender effect



Note. values in square brackets indicate 95% confidence interval. Two-tailed significance: ** $p < .01$.

Table 2 shows gender-specific differences in the *changes in own certainty* depending on different levels of *perceived uncertainty in the group*. For men, being confronted with uncertainty in the group led to a rapid decrease in own certainty, whereas women's certainty remained relatively stable even when perceiving high uncertainty in the group. It thus seems that the dampening effect of uncertainty in a learning group is stronger for men, leading to an overall decrease in certainty when perceiving the group to be uncertain only for men.

Table 2
Gender-specific changes in own certainty depending on perceived uncertainty within the group

perceived uncertainty within the group	changes in own certainty	
	female	male
low	0.281	0.528
neutral	0.166	-0.244
high	0.052	-1.016

Discussion

Taken together, we found uncertainty markers in social media posts to affect how learners perceive the certainty within the learning group. While this seems not surprising, it does mean learners are aware of the textual features and sensitive towards these markers. Further, it seems to have clear implications for the self-regulation of learning as perceived uncertainty within the social group seems to "rub off" on learners. While one would assume learners to become more confident during learning due to actual knowledge gained, overall, confidence seemed to be rather stable overall. However, the higher the perceived uncertainty, the lower this gain was. Furthermore, while women seemed to rather gain confidence under all conditions of perceived uncertainty within the group and rather less affected by the latter, men gained confidence when group uncertainty was judged low, but severely lost confidence in their assumptions when they perceived high uncertainty within the group. Thus, men seem to react stronger to social stimuli than women. This is surprising, as women are traditionally assumed to be more susceptible to social influence (Eagly & Carli, 1981) and better to perceive social stimuli (e.g., Bai et al., 2015), although scientific

results paint a much more pronounced picture. For example, there are indications that men may be more susceptible to social learning (Abdullahi et al., 2019) while other studies found not such effect but personality traits to be the important determinants (Oyibo & Vassileva, 2019). As sample characteristics may be one influencing factor and sample sized did vary between both gender groups in our study, further research needs to replicate found effects to unveil the mechanisms leading to these differences.

As expected, perceived uncertainty within the group also led to more changes in own assumptions and an increase in learning intention. Both effects were mediated by changes in own certainty. The results show that effects found regarding explicitly presented metacognitive awareness information (e.g., Schnaubert & Bodemer, 2016; Schnaubert et al., 2021) are transferable to more implicit markers in communication. This stresses the relevance of understanding the effects social contexts have on metacognitive self-regulation in digital and social learning environments. Further, it shows that language characteristics affect metacognitive group awareness. Linguistic markers are important to understand online communication and knowledge exchange even in anonymous online groups as communication not only contains content-information, but contextual cues used to generate group awareness (see Engelmann et al., 2009), which is also relevant for individual learning processes in digital and social learning environments (e.g., Heimbuch & Bodemer, 2017). While we focused our study on individual effects in social contexts, a logical next step seems to be the transfer to collaborative interaction processes. Apart from effects on metacognitive self-regulation and usage of the information about social metacognition for evaluating and regulating own learning processes, linguistic markers may provide valuable awareness information to appropriately interact with learning partners, for example by focusing on uncertain content (Schnaubert & Bodemer, 2019) or providing explanations to peers (Dehler et al., 2011). The correct interpretation of the metacognitive messages is crucial, as an incorrect interpretation may lead to misunderstandings and emotional conflicts, which could have a counterproductive effect on the learning process (Chiu & Kuo, 2008). Especially on large online learning platforms, when learners often do not know their peers and many communication-related aspects relevant to building group awareness may be unavailable, group awareness tools may be used to support collaboration and knowledge exchange (e.g., Janssen & Bodemer, 2013). However, without such tools, learners need to look for other cues to judge their social context and it is vital to understand how learners gain group awareness in unsupported learning settings (Schnaubert & Bodemer, 2022).

As we used a number of uncertainty markers, further research should look into more subtle differences in linguistic or speech characteristics and may use real online communication to determine the effects of uncertainty markers on metacognitive group awareness and subsequent effects on metacognitive monitoring and learning regulation in real online learning scenarios. Integrating this research with language technology to detect further uncertainty markers and estimate their effect on uncertainty perception (e.g., Pon-Barry & Shieber, 2011) would provide further insights into (social) metacognitive processes in digital and social learning environments.

References

Abdullahi, A. M., Oyibo, K., Orji, R., & Kawu, A. A. (2019). The influence of age, gender, and cognitive ability on the susceptibility to persuasive strategies. *Information, 10*(11), 352. https://doi.org/10.3390/info10110352

Anselme, P. (2010). The uncertainty processing theory of motivation. *Behavioural Brain Research, 208*(2), 291–310. https://doi.org/10.1016/j.bbr.2009.12.020

Bai, Y., Yamanashi Leib, A., Puri, A., Whitney, D., & Peng, K. (2015). Gender differences in crowd perception. *Frontiers in Psychology, 6,* 1300. https://doi.org/10.3389/fpsyg.2015.01300

Bernstein, B. (1962). Social class, linguistic codes and grammatical elements. *Language and Speech, 5*, 221–240. https://doi.org/10.1177/002383096200500405

Bidjerano, T. (2005). *Gender differences in self-regulated learning* (ED490777). ERIC. http://files.eric.ed.gov/fulltext/ED490777.pdf

Blankenship, K. L., & Holtgraves, T. (2005). The role of different markers of linguistic powerlessness in persuasion. *Journal of Language and Social Psychology, 24*(1), 3–24. https://doi.org/10.1177/0261927x04273034

Bodemer, D., & Dehler, J. (2011). Group awareness in CSCL environments. *Computers in Human Behavior, 27*(3), 1043–1045. https://doi.org/10.1016/j.chb.2010.07.014

Buder, J., & Bodemer, D. (2011). Group awareness tools for controversial CSCL discussions: Dissociating rating effects and visualized feedback effects. In H. Spada, G. Stahl, N. Miyake, & N. Law (Eds.), *Connecting computer-supported collaborative learning to policy and practice: CSCL 2011* (pp. 358–365). ISLS.

Carr, M., & Jessup, D. L. (1997). Gender differences in first-grade mathematics strategy use: Social and metacognitive influences. *Journal of Educational psychology, 89*(2), 318–328. https://doi.org/10.1037/0022-0663.89.2.318

Carver, R. P. (1990). *Reading rate: a review of research and theory*. Academic Press.
Chiu, M. M. (2008). Flowing toward correct contributions during group problem solving: A statistical discourse analysis. *Journal of the Learning Sciences, 17*(3), 415–463. https://doi.org/10.1080/10508400802224830
Chiu, M. M., & Kuo, S. W. (2008). Social metacognition in groups: Benefits, difficulties, learning and teaching. In C. B. Larson (Ed.), *Metacognition: New research developments* (pp. 117–136). Nova Science Publishers.
Dehler, J., Bodemer, D., Buder, J., & Hesse, F. W. (2011). Guiding knowledge communication in CSCL via group knowledge awareness. *Computers in Human Behavior, 27*(3), 1068–1078. https://doi.org/10.1016/j.chb.2010.05.018
Durik, A. M., Britt, M. A., Reynolds, R., & Storey, J. (2008). The effects of hedges in persuasive arguments. *Journal of Language and Social Psychology, 27*(3), 217–234. https://doi.org/10.1177/0261927x08317947
Eagly, A. H., & Carli, L. L. (1981). Sex of researchers and sex-typed communications as determinants of sex differences in influenceability: A meta-analysis of social influence studies. *Psychological Bulletin, 90*(1), 1–20. https://doi.org/10.1037/0033-2909.90.1.1
Engelmann, T., Dehler, J., Bodemer, D., & Buder, J. (2009). Knowledge awareness in CSCL: A psychological perspective. *Computers in Human Behavior, 25*(4), 949–960. https://doi.org/10.1016/j.chb.2009.04.004
Flavell, J. H. (1979). Metacognition and cognitive monitoring: A new area of cognitive–developmental inquiry. *American Psychologist, 34*(10), 906–911. https://doi.org/10.1037/ 0003-066X.34.10.906
Gigerenzer, G., Hoffrage, U., & Kleinbölting, H. (1991). Probabilistic mental models: A Brunswikian theory of confidence. *Psychological Review, 98*(4), 506–528. https://doi.org/10.1037/0033- 295X. 98.4.506
Green, M. (1984). Cognitive stage differences in types of speaker uncertainty markers. *Language and Speech, 27*(4), 323–331. https://doi.org/10.1177/002383098402700403
Hayes, A. F. (2017). *Introduction to mediation, moderation, and conditional process analysis: A regression-based approach*. Guilford publications.
Heimbuch, S., & Bodemer, D. (2017). Controversy awareness on evidence-led discussions as guidance for students in wiki-based learning. *The Internet and Higher Education, 33*, 1–14. https://doi.org/10.1016/j.iheduc.2016.12.001
Heimbuch, S., Ollesch, L., & Bodemer, D. (2018). Comparing effects of two collaboration scripts on learning activities for wiki-based environments. *International Journal of Computer-Supported Collaborative Learning, 13*(3), 331–357. https://doi.org/10/gfbnrs
Hosman, L. A., Huebner, T. M., & Siltanen, S. A. (2002). The impact of power of speech style, argument strength, and need for cognition on impression formation, cognitive responses, and persuasion. *Journal of Language and Social Psychology, 21*, 361–379. https://doi.org/10.1177/026192702237954
Howard-Jones, P. A., & Demetriou, S. (2009). Uncertainty and engagement with learning games. *Instructional Science, 37*, 519–536. https://doi.org/10.1007/S11251-008-9073-6
Janssen, J., & Bodemer, D. (2013). Coordinated computer-supported collaborative learning: Awareness and awareness tools. *Educational Psychologist, 48*(1), 40–55. https://doi.org/10.1080/00461520.2012.749153
Jordan, M. E., & McDaniel Jr., R. R. (2014). Managing uncertainty during collaborative problem solving in elementary school teams: The role of peer influence in robotics engineering activity. *Journal of the Learning Sciences*, *23*(4), 490–536. https://doi.org/10.1080/10508406.2014.896254
Jost, J.T., Kruglanski, A.W., & Nelson T.O. (1998). Social metacognition: An expansionist review. *Personality and Social Psychology Review, 2*(1), 137–154. https://doi.org/10.1207/ s15327957pspr0202_6
Juanchich, M., Gourdon-Kanhukamwe, A., & Sirota, M. (2017). "I am uncertain" vs "it is uncertain". How linguistic markers of the uncertainty source affect uncertainty communication. *Judgment and Decision Making*, *12*(5), 445–465.
Karabenick, S. A. (1996). Social influences on metacognition: Effects of colearner questioning on comprehension monitoring. *Journal of Educational Psychology, 88*(4), 689–703. https://doi.org/10.1037/0022-0663.88.4.689
Mäkitalo, K., Weinberger, A., Häkkinen, P., Järvelä, S., & Fischer, F. (2005). Epistemic cooperation scripts in online learning environments: Fostering learning by reducing uncertainty in discourse? *Computers in Human Behavior*, *21*(4), 603–622. https://doi.org/10.1016/j.chb.2004.10.033
McGarty, C., Turner, J. C., Oakes, P. J., & Haslam, S. A. (1993). The creation of uncertainty in the influence process: The roles of stimulus information and disagreement with similar others. *European Journal of Social Psychology, 23*(1), 17–38. https://doi.org/10.1002/ejsp.2420230103

Nelson, T. O., & Narens, L. (1990). Metamemory: A theoretical framework and new findings. In G. H. Bower (Ed.), *Psychology of learning & motivation* (pp. 125–173). Academic Press. https://doi.org/10.1016/S0079-7421(08)60053-5

Oyibo, K., & Vassileva, J. (2019). The relationship between personality traits and susceptibility to social influence. *Computers in Human Behavior*, *98*, 174–188. https://doi.org/10.1016/j.chb.2019.01.032

Ozcelik, E., Cagiltay, N. E., & Ozcelik, N. S. (2013). The effect of uncertainty on learning in game-like environments. *Computers & Education*, *67*, 12–20. https://doi.org/10.1016/j.compedu.2013.02.009

Pon-Barry, H., & Shieber, S. M. (2011). Recognizing uncertainty in speech. *EURASIP Journal on Advances in Signal Processing, 2011*(1), 1–11. https://doi.org/10.1155/2011/251753

Price, P. C., & Stone, E. R. (2004). Intuitive evaluation of likelihood judgment producers: Evidence for a confidence heuristic. *Journal of Behavioral Decision Making, 17*(1), 39–57. https://doi.org/10.1002/bdm.460

Renner, C. H., & Renner, M. J. (2001). But I thought I knew that: Using confidence estimation as a debiasing technique to improve classroom performance. *Applied Cognitive Psychology, 15*, 23–32. https://doi.org/10.1002/1099-0720(200101/02)15:1<23::AID-ACP681>3.0.CO;2-J

Salonen, P., Vauras, M., & Efklides, A. (2005). Social interaction—What can it tell us about metacognition and coregulation in learning? *European Psychologist, 10*(3), 199–208. https://doi.org/10.1027/1016-9040.10.3.199

Schnaubert, L., & Bodemer, D. (2016). How socio-cognitive information affects individual study decisions. In C.-K. Looi, J. Polman, U. Cress, & P. Reimann (Eds.), *Transforming Learning, Empowering Learners: The International Conference of the Learning Sciences (ICLS) 2016 (Vol. 1)* (pp. 274–281). ISLS.

Schnaubert, L., & Bodemer, D. (2017). Prompting and visualising monitoring outcomes: Guiding self-regulatory processes with confidence judgments. *Learning and Instruction, 49,* 251–262. https://doi.org/10.1016/j.learninstruc.2017.03.004

Schnaubert, L., & Bodemer, D. (2019). Providing different types of group awareness information to guide collaborative learning. *International Journal of Computer-Supported Collaborative Learning, 14*(1), 7–51. https://doi.org/10.1007/s11412-018-9293-y

Schnaubert, L., & Bodemer, D. (2022). Group awareness and regulation in computer-supported collaborative learning. *International Journal of Computer-Supported Collaborative Learning.* Advance online publication. https://doi.org/10.1007/s11412-022-09361-1

Schnaubert, L., Krukowski, S., & Bodemer, D. (2021). Assumptions and confidence of others: The impact of socio-cognitive information on metacognitive self-regulation. *Metacognition and Learning, 16,* 855–887. https://doi.org/10.1007/s11409-021-09269-5

Schneider, S., Beege, M., Nebel, S., Schnaubert, L., & Rey, G. D. (2022). The Cognitive-Affective-Social Theory of Learning in digital Environments (CASTLE). *Educational Psychology Review, 34,* 1–38. https://doi.org/10.1007/s10648-021-09626-5

Tenney, E. R., Small, J. E., Kondrad, R. L., Jaswal, V. K., & Spellman, B. A. (2011). Accuracy, confidence, and calibration: How young children and adults assess credibility. *Developmental Psychology, 47*(4), 1065–1077. https://doi.org/10.1037/a0023273

Thiede, K. W. (1999). The importance of monitoring and self-regulation during multitrial learning. *Psychonomic Bulletin & Review, 6*(4), 662–667. https://doi.org/10.3758/BF03212976.

Thiede, K. W., Anderson, M. C. M., & Therriault, D. (2003). Accuracy of metacognitive monitoring affects learning of texts. *Journal of Educational Psychology, 95*(1), 66–73. http://doi.org/10.1037/0022-0663.95.1.66

Tsovaltzi, D., Judele, R., Puhl, T., & Weinberger, A. (2015). Scripts, individual preparation and group awareness support in the service of learning in Facebook: How does CSCL compare to social networking sites? *Computers in Human Behavior, 53*, 577–592. https://doi.org/10.1016/j.chb.2015.04.067

Von der Linden, N., & Roebers, C. M. (2006). Developmental changes in uncertainty monitoring during an event recall task. *Metacognition and Learning*, *1*(3), 213–228. https://doi.org/10.1007/s11409-006-9001-6

Winne, P. H., & Hadwin, A. F. (1998). Studying as self-regulated learning. In D. J. Hacker, J. Dunlosky, & A. C. Graesser (Eds.), *Metacognition in educational theory and practice* (pp. 277–304). Lawrence Erlbaum.

Zimmerman, B. J., & Martinez-Pons, M. (1990). Student differences in self-regulated learning: Relating grade, sex, and giftedness to self-efficacy and strategy use. *Journal of Educational Psychology, 82*(1), 51–59. https://doi.org/10.1037/0022-0663.82.1.51